



Polar bear denning distribution in the Canadian Arctic

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Received: 16 September 2019 / Revised: 27 February 2020 / Accepted: 24 March 2020 / Published online: 2 April 2020
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Abstract

Declines in Arctic sea ice associated with climate change have resulted in habitat loss for ice-adapted species, while facilitating increased human development at higher latitudes. Development increases land-use and shipping traffic, which can threaten ecologically and culturally important species. Female polar bears (*Ursus maritimus*) and cubs are susceptible to disturbance during denning; a better understanding of denning habitat distribution may aid management. We compiled existing location data on polar bear denning ($n = 64$ sources) in Canada between 1967 and 2018, including traditional ecological knowledge (TEK) studies, government and consultant reports, peer-reviewed scientific articles, and unpublished data acquired through data-sharing agreements. We synthesized these data to create a map of known denning locations. Most coastal regions in northern Canada supported denning, but large areas exist where denning is unreported. Gaps remain in the knowledge of polar bear denning in Canada and filling these will aid the conservation and management of polar bears in a changing Arctic.

Keywords *Ursus maritimus* · Climate change · Denning · Habitat · Traditional ecological knowledge

Introduction

Climate change has led to sea ice loss that is projected to continue through the next century (Stroeve and Notz 2015). Spatio-temporal declines in sea ice have been linked to shifts in ice-adapted species' foraging (Sciullo et al. 2017), distribution (Derocher et al. 2011), movement (Yurkowski et al. 2016), and reproduction (Ferguson et al. 2017). Many sea ice changes (e.g., reduced duration, extent, thickness) that are considered negative for Arctic wildlife may allow increased

human access and industrial development (Burgass et al. 2018). The combination of habitat loss and increased disturbance can have negative consequences for wildlife if not managed (e.g., Polfus et al. 2011; Plante et al. 2018). Given the pace of Arctic warming and human activities, identifying important habitats and establishing protected areas for ecologically and culturally important species will become increasingly important.

Polar bears (*Ursus maritimus*) have a circumpolar Arctic range relying on sea ice habitats for traveling, hunting, and mating (Amstrup 2003). Similarly, the distribution of maternal denning is reliant on suitable habitat. Pregnant females typically den in snow banks or peat deposits on land

Electronic supplementary material The online version of this article (<https://doi.org/10.1007/s00300-020-02657-8>) contains supplementary material, which is available to authorized users.

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and less frequently on sea ice where snow has accumulated (e.g., Kolenosky and Prevet 1983; Durner et al. 2003). Polar bears are seasonal breeders: mating occurs in the spring and implantation is delayed until the autumn when pregnant females construct and enter dens (Harington 1968; Ramsay and Stirling 1988). Gestation, parturition, and lactation occur in the den over winter (Nelson et al. 1983). Maternity dens provide shelter from Arctic conditions (Ramsay and Stirling 1988). Premature exposure of altricial cubs or disturbance of denning bears can result in reproductive failure (Ramsay and Dunbrack 1986; Amstrup and Gardner 1994; Linnell et al. 2000). Due to this vulnerability, denning areas were identified in the 1973 Agreement on the Conservation of Polar Bears as requiring special attention (Prestrud and Stirling 1994) and are considered critical habitat to protect in land-use plans (e.g., North Baffin Regional Land Use Plan).

Threats to denning polar bears may come from human disturbance and/or natural events associated with climate change. Threats from northern development can include seismic surveys, building of ice roads, and environmental contaminants (e.g., Amstrup 1993; Kerr 2002; Nuijten et al. 2016). Anthropogenic activities are expected to increase in intensity over time (Laidre et al. 2015) and subsequently increase the complexity for management to mitigate risks to Arctic wildlife. Climate change-related impacts may also threaten polar bear denning habitat. For example, an increase in forest fire activity and permafrost melting in peat habitat can destroy den habitat (Richardson et al. 2007). Winter rain can cause den collapse (Clarkson and Irish 1991) and reduced snow depth have been suggested as emerging threats over the entire range (Derocher et al. 2004; Hezel et al. 2012). Assessing and predicting the risk associated with these threats necessitate information on the distribution of denning habitat used by pregnant female polar bears.

Numerous studies on polar bear maternity denning have been conducted across Canada, but most focus on specific populations. The distribution of polar bear denning is available for Alaska (Durner et al. 2010) and Svalbard (Andersen et al. 2012); however, a similar compilation does not exist for Canada. Successful conservation of species and their habitats are linked to stakeholder engagement and participation (e.g., Kainer et al. 2009). For polar bears, additional information is held within communities as traditional ecological knowledge (TEK; a component of Inuit Qaujimagatugangit; Usher 2000). Incorporation of TEK in decision making is part of polar bear conservation in Canada (Peacock et al. 2011) and thus should be incorporated into the cumulative knowledge of a species.

Our objectives were to (1) review and compile existing information on polar bear denning areas in Canada in an accessible database and (2) create a comprehensive map of all known polar bear denning locations. An accessible database and comprehensive map of denning regions are

useful for managers when identifying critical habitat for polar bears.

Materials and methods

Data aggregation

We located information sources on polar bear maternity denning throughout their range in Canada (Online Resource 1). Some polar bears use temporary dens (Harington 1968), but those were outside of the scope of this study and not included. Data sources included TEK studies, peer-reviewed literature, and government reports. We also obtained unpublished data from some jurisdictions. For each source, we collected metadata information on the publication, region (management unit), type of data (point or polygon), and the publication type (Survey, Knowledge, or Review; see Online Resource 1).

Den map creation

Information on polar bear denning areas, ranging from broad areas to locations of individual dens, were added to a geographic information system (GIS) database in ArcGIS® 10.3 (ESRI Inc., Redlands, CA, USA). Data were available as follows: (a) map point data (location of a den on a map or GPS coordinates); (b) map polygon data (location of denning area provided on a map); (c) descriptive point data (a description of a point where a den was observed; and/or (d) descriptive polygon (a description of an area that supports denning). Map data (a and b) were geo-referenced into the GIS database. Descriptive data (c and d) were interpreted subjectively; we developed a series of protocols to limit subjectivity of the descriptive data (Online Resource 2). Each map that provided denning information was scanned and converted to a JPEG image, geo-referenced onto a GCS_North_American_1983 map, and projected in the Canada Lambert Conformal Conic coordinate system. As precisely as possible, points and polygons representing dens or denning areas (respectively) were digitized using ArcGIS®.

Results

We obtained denning location data from 64 different sources (Online Resource 1) that contributed 1593 den location points and 430 denning area polygons that we have presented on a map (Fig. 1). We found most of the coastal regions of the Canadian range of polar bears were identified as having dens. Denning was not uniformly distributed, with rare occurrences of denning in Nunavik (Quebec), Nunatsiavut (Labrador), and the western Canadian High-Arctic

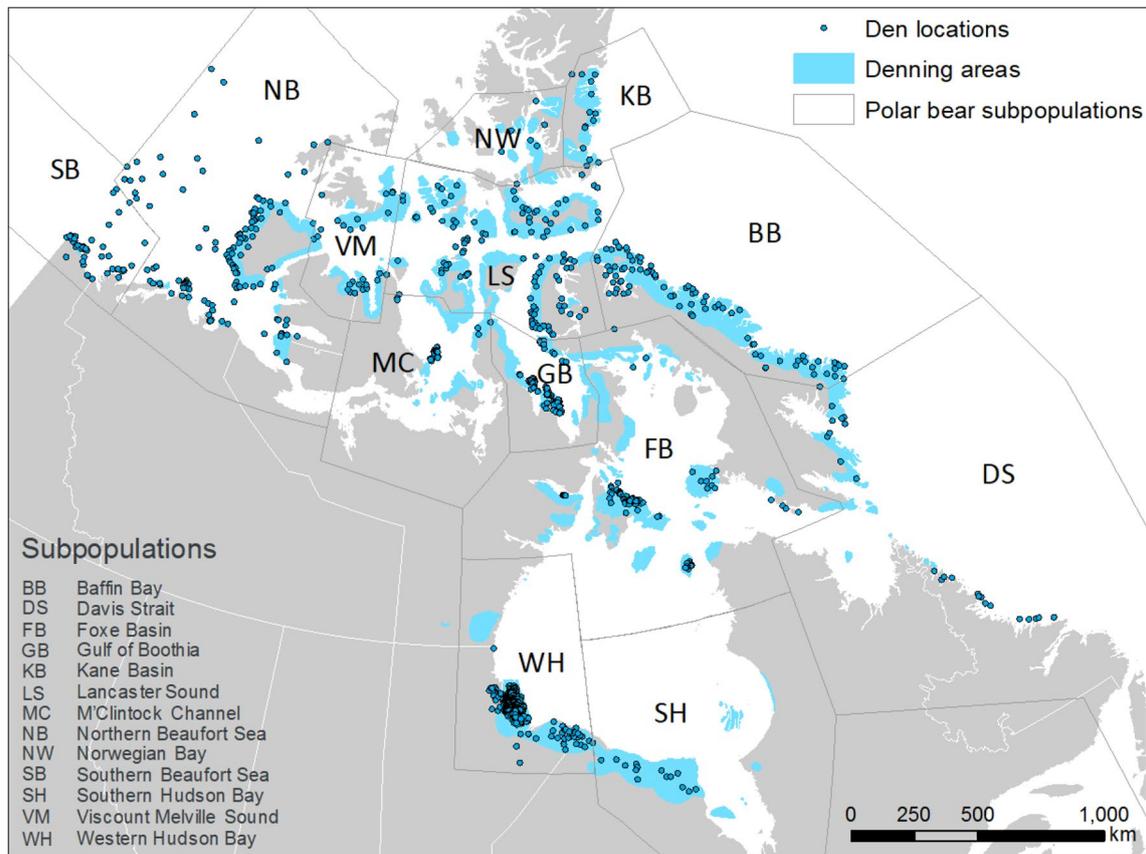


Fig. 1 Map of observed polar bear maternity dens (blue dots) and denning areas (blue shaded polygons) in the Canadian Arctic derived from traditional ecological knowledge (TEK) studies, government and consultant reports, peer-reviewed scientific articles, and unpublished data. These areas reflect published records of denning; areas

with no denning areas shown do not necessarily indicate that denning does not occur. *Note* the circles identify dens with coordinate data but each is scaled for visual purposes: the entire area underneath the circle does not necessarily represent denning areas

(Fig. 1). While most denning occurred on land (e.g., Clark et al. 1997; Richardson et al. 2005), there were numerous records of denning on pack-ice in the Beaufort Sea (e.g., Durner et al. 2010; Rode et al. 2018), and on land-fast ice throughout the Canadian Arctic Archipelago (e.g., Stirling et al. 1978; Ferguson et al. 2000).

Discussion

We provide a map of available polar bear denning records in Canada. High-density polar bear denning areas can be considered critical habitat and our compilation may provide conservation insights in the face of climate change and increased disturbance.

Polar bear denning was recorded in many coastal regions of the Canadian Arctic and sub-Arctic (Fig. 1), but the distribution ranged from areas of high density to areas with no reports of denning. On a fine scale, den habitat has been related to landscape features such as snow, peat banks, tree

cover, topography, and aspect (Harington 1968; Kolenosky and Prevet 1983). Topography and aspect are especially important for the formation of stable snow drifts that will persist for the entire denning period (Liston et al. 2016). Land-fast ice is the preferred habitat for females emerging from dens (Pilfold et al. 2014) and den sites are possibly selected due to their proximity to spring hunting areas. Our results suggest denning habitat is more evenly distributed across much of the northern extent of the Canadian polar bear range, but is more patchy and concentrated in the southern extent of polar bears range (e.g., western and southern Hudson Bay). In Manitoba specifically, the large number of observed polar bear dens in Wapusk National Park (Fig. 1) may be due to specific habitat characteristics (e.g., concentration of suitable habitat).

Offshore polar bear denning primarily occurred on the land-fast ice throughout the Canadian Arctic Archipelago (Fig. 1); denning on offshore pack-ice was also recorded, and exclusively occurred in the Beaufort Sea. Monitoring activities in the Chukchi and Beaufort seas, extending into

the western Canadian Arctic, have observed southward and eastward shifts in pack-ice den distribution (in some cases from sea ice to land), in response to reduced multiyear sea ice, increased unconsolidated ice, and increased duration of melt season (Fischbach et al. 2007; Olson et al. 2017). There were no published records of offshore pack-ice denning on other Canadian seascapes (e.g., Hudson Bay, Baffin Bay), perhaps because terrestrial denning is preferred, or sea ice is too unstable. Denning on sea ice in the Beaufort Sea may have resulted from historic terrestrial harvest pressure that depleted those females that denned on land (Stirling and Andriashek 1992) and the close proximity of multiyear sea ice over the continental shelf.

Reporting of polar bear denning was not uniform across the Canadian Arctic. In particular, we note three regions with sparse data: (1) Nunavik (Quebec); (2) Nunatsiavut (Labrador); and (3) the western Canadian High-Arctic. This is in spite of the presence of polar bear subpopulations (Fig. 1) that occupy adjacent marine areas. Although few den records suggests that data are missing, recent TEK reports provide information that denning occurs but do not identify high-density denning areas in these regions (e.g., Slavik 2013; IJS 2015; NMRWB 2018), suggesting that dens are dispersed over the landscape at low density. The information available on dens also reflects the intensity of research in various areas. For example, the Western Hudson Bay population has been extensively studied since the 1960s (Vongraven et al. 2018) with 14 publications/reports on polar bear denning, including repeated surveys for dens, and subsequently, a high density of den locations (e.g., Richardson et al. 2005).

While we recognize that polar bears may den in areas not identified by our research, the Canadian Arctic has been widely studied and by combining these data with TEK, we think that major denning areas have not been overlooked. Our analyses identified areas with low den numbers for which we were unable to determine if sampling effort or lack of use is the cause of these gaps. Therefore, environmental impact reviews should consider our data as a base to which local knowledge, recorded in the future, may be added.

A large portion of polar bear denning data (35% of sources), both historical and recent, was derived from publications of TEK. This highlights the importance of including and recording the knowledge of species held in indigenous communities (Usher 2000). TEK can cover large spatio-temporal scales, local perspectives, and incorporate pre-existing, but unrecorded data. As such, an interdisciplinary approach (i.e., combining TEK and survey data) to conservation biology facilitates partnerships, integrates local priorities, and provides insights into wildlife ecology.

The long-term observations of shifting den distribution in the Beaufort Sea (primarily offshore the Alaskan coast; Fischbach et al. 2007; Olson et al. 2017) and Baffin Bay

and Kane Basin (Escajeda et al. 2018) stress the importance of polar bear den monitoring across the Canadian Arctic so shifts may be detected and managed accordingly. Continued or increased monitoring could provide insight to the response of female polar bears to habitat changes and increased human activity.

Acknowledgements This research was funded in part by World Wildlife Fund (WWF) Canada; the results and recommendations presented in this paper do not necessarily represent the official position of WWF-Canada. We also gratefully acknowledge financial support from the Assiniboine Park Conservancy and Project Learning Tree. We thank Heather Penner for data compilation assistance, Geoff York for support during initial project work, and David Yurkowski and two anonymous reviewers for helpful comments on earlier versions of the manuscript.

Conflict of interest The authors declare that they have no conflicts of interest.

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